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Moon Colonization for Human civilization: Theoretical Overview

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Abstract. Space colonization or space settlement or extra-terrestrial colonization is hypothetical permanent habitation and exploitation of natural resources from outside spaceflight or operating space outputs. The primary argument calling for space colonization is the long-term survival of human civilization and terrestrial life. By developing alternative locations off Earth, the planet's species, including humans, could live on in the event of natural or human made disasters on our own planet. Colonizing a natural body would provide an ample source of material for construction and other uses in space, including shielding from cosmic radiation. The energy required to send objects from the Moon to space is much less than from Earth to space. The objective of this paper is to study the basic requirements and environment and issues (medical and technical) to face while colonizing the moon. Its base, sides of the moon, soil,gravity requirements, water form particles, etc. This paper also presented the internal structure of the Moon, its design criteria, gravitation, challenges, risk/safety, etc.

1. Introduction

Moon is the natural satellite of Earth. It is the largest satellite in our solar system. Its surface gravity is about one-sixth of Earth's. The Moon is in synchronous rotation with Earth. Its near side is marked by large dark plains (volcanic 'maria') that fill the spaces between the bright ancient crustal highlands and the prominent impact craters. The Moon's surface is actually dark. Although compared to the night sky it appears very bright, with a reflectance just slightly higher than that of worn asphalt. Its gravitational influence produces the ocean tides, and the slight lengthening of the day. The Moon is moving approximately 3.8 cm away from our planet every year. As we know, the Moon is partly responsible for causing the tides of our oceans and seas on Earth, with the Sun also having an effect. However, as the Moon orbits the Earth it also causes a tide of rock to rise and fall in the same way as it does with the water. The effect is not as dramatic as with the oceans but nevertheless, it is a measurable effect, with the solid surface of the Earth moving by several centimeters with each tide. These effects result in the Moon being viewed from slightly different angles, and more of the surface being viewed over time. The surface of the Moon is covered in huge dark spots, visible from Earth even with the naked eye. The black spots on the Moon are called synchronous rotation. In all, about 59 percent of the Moon is sea visible from Earth over the course of an orbit. Those spots are called Maria, from the Latin word for. S. Kirchevsky et. al. (2020) studied various aspects of Moon, definition of Moon Exploration concept, its brief description, history, exploration and colonization of Moon. Moon exploration is a goal-oriented process of human activity on an exploration of the Moon embracing study, research and usage of the Moon, all attributes of it, of its surface, subsoil, resources with the aim of survival and development of human and society on Earth and beyond Earth, on the Moon, reaching the point of total exploration and total colonization of the Moon [1]. Ankit et.al summarized the planetary formation and its stages after the huge explosion of big bang and completely accepting the nebular hypothesis. This hypothesis is mostly accepted explanation for how the sun and the planets and solar system may have formed. About 13.8 billion years ago the universe was formed [2]. Study on composition of chemical substances affecting the launch vehicle in ground station as well as atmospheric conditions were made. During the rocket-launching the large amount of inhalation of an exhaust gas released and it majorly affects the surface of the launch pad as well as the atmosphere. In rocket, the combustion produces huge number of hot gases with high temperature and pressure [3].

2. Methodology

Design criteria: While designing the Moon base there are some factors which must be kept in mind, performance, reliability, safety and cost. As per standard engineering design approach the cost is the most important aspect in designing criteria. There are other important factors are storage, resupply and recycling. Storage and resupply include oxygen tanks and containers, water tanks and containers and recycling includes Carbon Dioxide Removal Assembly (CDRA), Carbon Dioxide Reduction System (CRDS), Oxygen Generation System (OGS), Water Processor Assembly (WPA), and Urine Processor Assembly (UPA).

Gravitation of moon: The acceleration due to gravity on the surface of the moon is approximately 1.625 m/s^2, about 16.6% that on earth's surface. Over the entire surface, the variation in gravitational acceleration is about 0.0253 m/s^2. Because weight is directly dependent upon gravitational acceleration, things on the moon will weigh only 16.6% of what they weigh on the earth. The gravitation field of the moon has been measured by tracking the radio signals emitted by orbiting spacecraft. It is measured by the principle of Doppler Effect. The moon's surface gravity is about 1/6th as powerful or about 1.6 meters per second per second as earth's average surface gravity is about 9.8 meters per second per second.

TABLE 1. Comparison between Moon and Earth

Parameters	**Moon**	**Earth**
Equatorial Radius	1738 km	6378 km
Mass	7.353*1022 kg	5.976*1024 kg
Mass Ratio	1:81	1:1
Mean Density	3.34 g/cm^3	5.517 g/cm^3
Surface Gravity	1.62 m/s^2	9.78 m/s^2
Escape Velocity	2.37 km/s	11.18 km/s
Atmospheric Pressure	10-14 atm	1 atm
Sidereal Rotation Time	27.322 days	23.9345 hours
Mean Surface Temperature	107 ˚C Day – 153 ˚C night	22 ˚C
Temperature Extremes	-233 ˚C to 123 ˚C	-89 ˚C to 58 ˚C
Seismic Activity	500 quakes/year	10,000 quakes/year
Magnetic Field Strength	$3*10^{-9}$ – $3.3*10^{-7t}$	$3.0*10^{-5t}$
Indigenous Life	No	Yes

Lunar Soil: The carbon, hydrogen and nitrogen found in the soil due to the solar winds. Lunar soil also has high concentrations of sulphur, iron, magnesium, manganese, calcium and nickel. As well as some oxides like FeO, MnO, MgO, etc., Ilmenites (FeTiO3), most common in the mare regions, is the best source of in situ oxygen.

The upper few hundred meters are believed to be rubble generated by tons of meteor bombardment. Micrometeorite impacts alone are sufficient to "churn" the entire regolith about every 40 million years. This process, assisted by the effects of radiation and the solar wind, accounts for the weathering of the lunar surface. Weathering has left the lunar soil with a relatively fine texture. The grain-size distribution present in the lunar soil is:

TABLE 2. Grain size distribution for lunar soil

Grain Size (mm)	**%Weight**
10-4	1.67
4-2	2.39

2-1	3.20
1-0.5	4.01
0.5-0.25	7.72
0.25-0.15	8.23
0.15-0.090	11.51
0.090-0.075	4.01
0.075-0.045	12.40
0.045-0.020	18.02
Less than 0.020	26.85

Lunar Atmosphere: The moon has an extremely thin atmosphere. Into the lunar atmosphere helium, argon, sodium and potassium have been identified as atmospheric elements. Of these, the helium most likely comes from the solar wind, while the argon originates in the lunar interior. The atmosphere is too weak to protect from the sunlight. During the month-long-lunar day, equatorial temperature can range from 400 K to 100 K, with rapid (5 k/hour) temperature changes at sunset and sunrise. In polar regions, the sun does not rise more than 1.5 degrees above the horizon. There are many crater floors which are in permanent shadow. These are the best sources to search for water, since these areas are constantly cold around 80K temperature. Three radiation sources affect the moon: galactic cosmic rays, solar flare particles, and solar wind particles (See Table).

TABLE 3. Radiation ranges for different parameters

Radiation Source	Energy	Flux (cm-2s-1)	Penetration Depth
Cosmic Rays	1 – 10 Gev/nucleon	1	Few meters
Solar Flares	1 – 100 Mev/ nucleon	100	1 cm
Solar Wind	1000 ev/ nucleon	108	10 - 8

Oxygen generation on moon: For development of life on any planet the most important factor required is the oxygen to breathe. If we want to develop the human colony on the lunar surface itself it will give us so many benefits and it is not possible to transport oxygen from the earth to the lunar surface because every kilogram of addition of weight to the spacecraft increases the amount of the fuel required and this adds to the cost of developing the spacecraft. If we are able to produce the oxygen on the lunar surface itself it will give us so many benefits. There is one way to generate oxygen on the moon from the lunar soil. Almost 45% of the lunar soil is made up of oxygen in the form of oxides with metals and non-metals. If we are able to extract the oxygen from the lunar soil, we can overcome the need of oxygen for colonization by some percent. This oxygen in the form of oxides can be obtained by breaking chemical bonds with the help of thermal, electrical or chemical energies. There are different methods that can be used to extract the oxygen from the lunar surface.

Water Production on Lunar Surface: Water was discovered on the moon in 2008 by Chandrayan-1 launched by ISRO. The existence of water on the lunar surface seems strange; the moon is directly exposed to the vacuum of space. Since its surface directly comes in contact with the sunlight, it evaporates into space. The water present on the moon is in its polar craters inthe form of ice. This water ice can be used to produce air, drinkable water, propellants and fuels that are needed for the lunar habitat. To convert ice present on the moon into useful water this is the one way to get the water on the lunar surface for the habitat. While there is another way also since lunar soil is made up from silica (SiO_2), when this reacts with thehydrogen atom the water molecule forms. The lunar dust grain is capable of creating the hydroxyl group (OH) a component of water molecules.

Water Mining on Lunar Surface: The hydrogen reduction plant which uses radical microwave technology will be used to extract the underground water ice present on the moon. This mined water may supply drinkable water, produce oxygen and may be used for fuel. The challenge with this technology is very expensive and it has to be tested on the lunar environment, then only wecan imagine habitat on the moon.

Plantation in Lunar Soil: Plants serve as a life supporting system as they provide us food. If we are able to grow plants on other planetslike the Moon then there will be significant reduction in the Equivalent System Mass (ESM) cost, as necessary food storage and life support apparatus get eliminated. At NASA Ames, life cycle trials with different lighting conditions have been run to observe how altered diurnal pattern of the moon could affect the plants. The Lunar day consists of 14 earths' day and night day consists of 14-night days at the lunar equator. If any object is exposed at the equator, then the temperature varies from -173 °C to 117 °C. No significant field on the moon, gravitation is about one sixth of earth's gravity, atmosphere is almost negligible, so heat transfer mechanism by convection is not possible and conduction through lunar regolith is also not possible since its conductivity is very low. The surface is constantly exposed to hazardous radiation. This environment is harmful to any tissue placed at the surface. Lunar surface has sand like soil or regolith, which contain all essential minerals required for the growth of the plants except reactive nitrogen. Nitrogen is a reactive form (NO_3, NH_4) is an essential mineral for the growth of plants. Metals like aluminium and chromium are also present in lunar soil which are known to disturb plant growth and may also lead to plant death. One more essential element is liquid water which is not present on the moon, the water present in the form of ice. The experiment on plant growth has been carried out by exposing them to the regolith of the moon which was carried back from the Apollo mission; it reports that there are no toxic effects on the short-term plant growth. By analyzing the mineral composition, soil particle size, and nutrients that are available for plant growth in thelunar soil, it revealed that Moon regolith is truly nutrient poor, though it contains a small number of nitrates of ammonium. Moon regolith has a high pH value which may be problematic for the growth of many plant species.

Inflatable design: Inflatable habitats have always been a favourite, optimizing living space whilst using lightweight materials. As the moon has no atmosphere (apart from some very tenuous gases being "outgassed" from its surface), any habitat would need to be highly pressurized to simulate the terrestrial atmosphere (to approximately 1 atmosphere or 101,325 Pa) and atmospheric gas quantities. There is however a massive problem with inflatables. Catastrophic depressurization could occur if a high velocity projectile causes weakness in the membrane.There are some solutions, such as covering the inflatable habitats with a layer of protective regolith and extensive fail-safes will need to be put in place.

Local materials: Ultimately, it is hoped that a settlement on the moon will have an infrastructure capable of mining local materials, fabricating basic quantities and constructing structures with little or no input from earth. This degree of autonomy would be required if a thriving moon base is to succeed. However, to maintain airtightness within the habitats, a new form of concrete would need to be manufactured. As the moon is sulphur-rich, a different type of concrete (minus the need for water) may be created to aid with the construction of arced and domed habitats.

Lava Tubes: Ancient Lava Tubes under the lunar surface exist and may be utilized by colonists. Using natural cavern systems will have many benefits; principally that minimal construction would be required. Many advocates for this plan point out there are too many risks associated with above surface structures; why not use natural shelterinstead? Lava tubes may be interconnected, allowing sizable settlements; also they may be easily sealed, allowing for pressurized habitats.

Structural Design: We saw hazards associated with building a base on another planet, and also explored some of the current design concepts for the first manned habitat on the Moon. The designs ranged from inflatable structures, habitats that could be constructed in Earth orbit and floated to the lunar surface, to bases hollowed out of ancient lava tubes under the surface.So the primary function must be to maintain air pressure and reduce the risk of catastrophic damage should the worst happen. The key factors influencing structural designs of habitats of the Moon are:

- One-sixth terrestrial gravity.
- High internal air pressure (to maintain a human-breathable atmosphere).
- Radiation shielding (from the Sun and other cosmic rays).
- Micrometeorite shielding.
- Hard vacuum effects on building materials (i.e., outgassing).
- Lunar dust contamination.
- Severe temperature gradients.

In addition, the lunar structures must be easy to maintain, inexpensive, easy to construct and compatible with other lunar habitats/modules/vehicles. As it turns out, the lunar regolith has many useful properties for the construction on the moon. To complement the lunar concrete, basic building structures may be formed from cast regolith. Cast regolith would be very similar to terrestrial cast basalt. Created by melting regolith in a mold and allowing it to cool slowly would allow a crystalline structure to form, resulting in highly compressive and moderately tensile building components. The high vacuum on the moon would greatly improve the manufacturing process of the material. Advantages using cast regolith are, it is very tough and resistant to erosion by lunar dust. It could be the ideal material to pave lunar rocket launch sites and construct debris shields surrounding landing pads.

Infrastructure and Transportation: Imagine trying to build a structure on the surface of the Moon. Two of the biggest obstacles the firstlunar settlers will come across are the very low gravity and the fine dust causing all sorts of construction issues. Future settlement of the Moon is dependent on the efficiency of the transport structure. It seems likely that most transportation around the Moon will depend on wheeled methods. So, we need to form a road infrastructure if wheeled transportation is used.

3. Conclusion

As a concluding remark, we have studied the considerable factors to colonize on the Moon. Factors such as water, atmosphere, oxygen, shelter, food, hygiene, electricity, soil, temperature, energy, etc. were compared with some of these parameters on the moon with earth's atmosphere. Also, this paper provides brief comparative study of lunar surface and earth surface, lunar atmosphere, lunar soil. In this weprovide brief information about production of oxygen, plantation, power generation and transportation, sanitization, conversion of water which is in the form of the ice present on the moon, saving astronauts from radiations and extreme temperatures.

References

[1]. Krichevsky, Sergey (2019) the exploration of the Moon: history, model, super global project, and environmentally friendly technologies. Aerospace Sphere Journal, Vol. 3, 16-25. https://doi.org/10.30981/2587-7992-2019-100-3-16-25.
[2]. Ankit Kumar Mishra, Sheetal, Nikkisha, MS Ragul, "Nebular hypothesis after an explosion of big bang: Theoretical approach", Journal of Emerging Technologies and Innovative Research, Volume 8(12), pp. a657-a663, December 2021.
[3]. D R. Pallavi, M. Ramachandran, Sathiyaraj Chinnasamy, "An Empirical Study On Effectiveness of E-Learning Over Conventional Class Room Learning – A Case Study with Respect to Online Degree Programmes in Higher Education", Recent trends in Management and Commerce, 3(1), (2022): 25-33
[4]. Ankit Kumar Mishra, MS Ragul, "Theoretical Model Study on Chemical Compositions Affecting the Space Launch Vehicles", REST Journal on Emerging Trends in Modelling and Manufacturing, vol. 8(1), 2022, https://doi.org/10.46632/jemm/8/1/6.
[5]. S. Sowmiya, M. Ramachandran, Sathiyaraj Chinnasamy, Vidhya Prasanth, Soniya Sriram, "A Study on Humanoid Robots and Its Psychological Evaluation", Design, Modelling and Fabrication of Advanced Robots, 1(1), (2022): 48-54
[6]. Khan, A., Mosegaard, K., 2002, "An enquiry into the lunar interior—a non-linear inversion of the Apollo lunar seismic data," Journal of Geophysical Research 107. http://dx.doi.org/ 10.1029/2001JE001658.
[7]. Lognonné, P., Gagnepain-Beyneix, J., Chenet, H., 2003. A new seismic model of the Moon: implications for structure, thermal evolution and formation of the Moon. Earth and Planetary Science Letters 211, 27.
[8]. C. Venkateswaran, M. Ramachandran, Sathiyaraj Chinnasamy, Chinnasami Sivaji, M. Amudha, "An Extensive Study on Gravitational Search Algorithm", Materials and its Characterization, 1(1), (2022): 9-16
[9]. Gagnepain-Beyneix, J., Chenet, H., Lognonné, Lombardi, D., Spohn, T., 2006. A seismic model of the lunar mantle and constraints on temperature and mineralogy. Physics of the Earth and Planetary Interiors 159, 140.
[10]. Khan, A., Maclennan, J., Taylor, S.R., Connolly, J.A.D., 2006a. Are the Earth and the Moon compositionally alike? —Inferences on lunar composition and implications for lunar origin and evolution from geophysical modeling. Journal of Geophysical Research 111. http://dx.doi.org/10.1029/2005JE002608.
[11]. https://en.wikipedia.org/wiki/Colonization_of_the_Moon#Lunar_water_ice
[12]. http://www.tsgc.utexas.edu/tadp/1995/spects/environment.html.
[13]. https://www.space.com/16903-mars-atmosphere-climate-weather.html